

A Wind-Driven Method for Assessing Nano- and Sub-micron Particle Penetration through Fabrics

Peter Jaques¹, Ta-Chih Hsiao², Pengfei Gao², Angie Shepherd², Benjamin Eimer¹, Mengshi Yang², Adam Miller², Bhupender Gupta³, and Ronald Shaffer²
¹URS Corp., Pittsburgh, PA, ²NIOSH/NPPTL, Pittsburgh, PA, ³North Carolina State University, Raleigh, NC

Introduction

- Protective clothing and garments are suggested as barriers against dermal exposures to nanoparticles in the workplace.
- However, there currently is little data available on particle penetration through various protective clothing materials.
- Most of the penetration data reported for protective clothing uses the filtration-based method, which may not be representative, because
 - in the real world, particle penetration through protective clothing is primarily driven by upstream wind, not drawn downstream by a vacuum pump, and
 - a stagnation zone that would be created by a human body behind the protective clothing will result in a change of flow streamlines and approaching particle trajectories.

Objectives

- To establish a test method that simulates particle penetration through test fabrics as driven by upstream wind.
- To evaluate the performance of ten different non-woven fabrics in particle sizes ranging from 30 to 500 nm.
- To investigate the impact of face velocity, particle size, and the fabric's physical properties.
- To compare the penetration levels of ten fabrics using the proposed wind-driven test method and a standard filtration-based method (TSI Model 3160 automated filter tester).

Proposed Wind-Driven Method

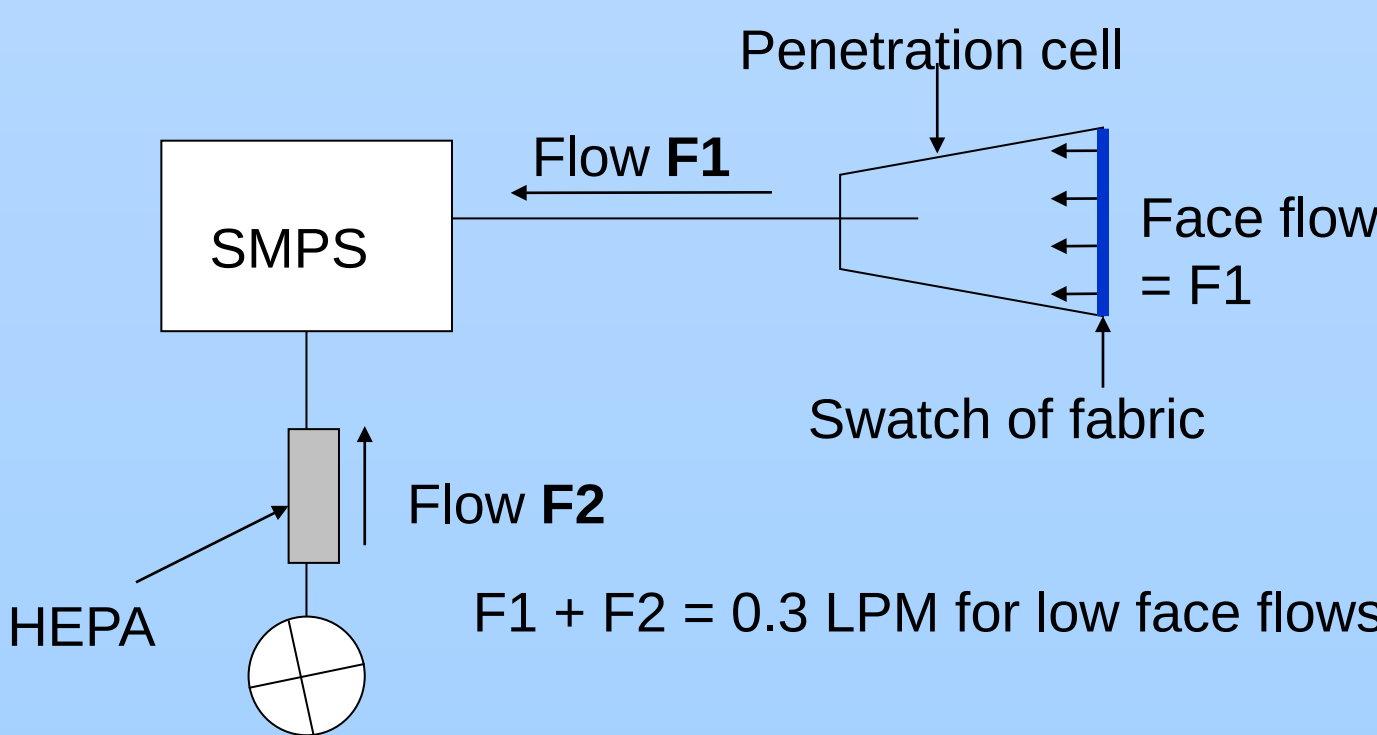


Figure 1. A wind tunnel recirculation aerosol chamber (WTRAC) produces air flow to mix and deliver aerosols to the penetration cell. Paired scanning mobility particle sizers (SMPS) measure particle concentrations inside and outside of the penetration cell. The vacuum force behind the test fabric swatch was minimized by carefully matching the sampling flow rate to the flow rate through the fabric (F1) that is caused by wind driven forces.

Nonwoven Test Materials and Properties

Sample ID	Material	Application	Structural Feature
A	Cellulose	Solvent Cleaning Cloth	resembling patterned wet-laid structure
B	Cellulose	Cleaning Cloth	two adhesive bonded layers reinforced by yarns between the layers
C	Cellulose	Wiping Cloth	adhesive bonded, fabric with patterned open spaces (perforations)
D	Cellulose	Machinery Wiping Cloth	4-layer structure, resembling wet-laid structure, reinforced with yarns along the length and width directions between the middle two layers
E	Poly propylene	Hospital Gown	thermally bonded patterned structures
F	Poly propylene	Hospital Frock	3-layer structure, resembling SMS, the outer two layers serve as the reinforcing while the inner layer provides the resistance to penetration for the fabric structures
G	Poly propylene	Hoodless Coveralls	similar to Fabric F
H	Poly propylene	Hair Net	highly open thermally bonded fabric with a pattern
I	Poly propylene	Hair Net	similar to Fabric H
J	Metaaramid	Firefighter ensemble insulation	needle-punched fabric

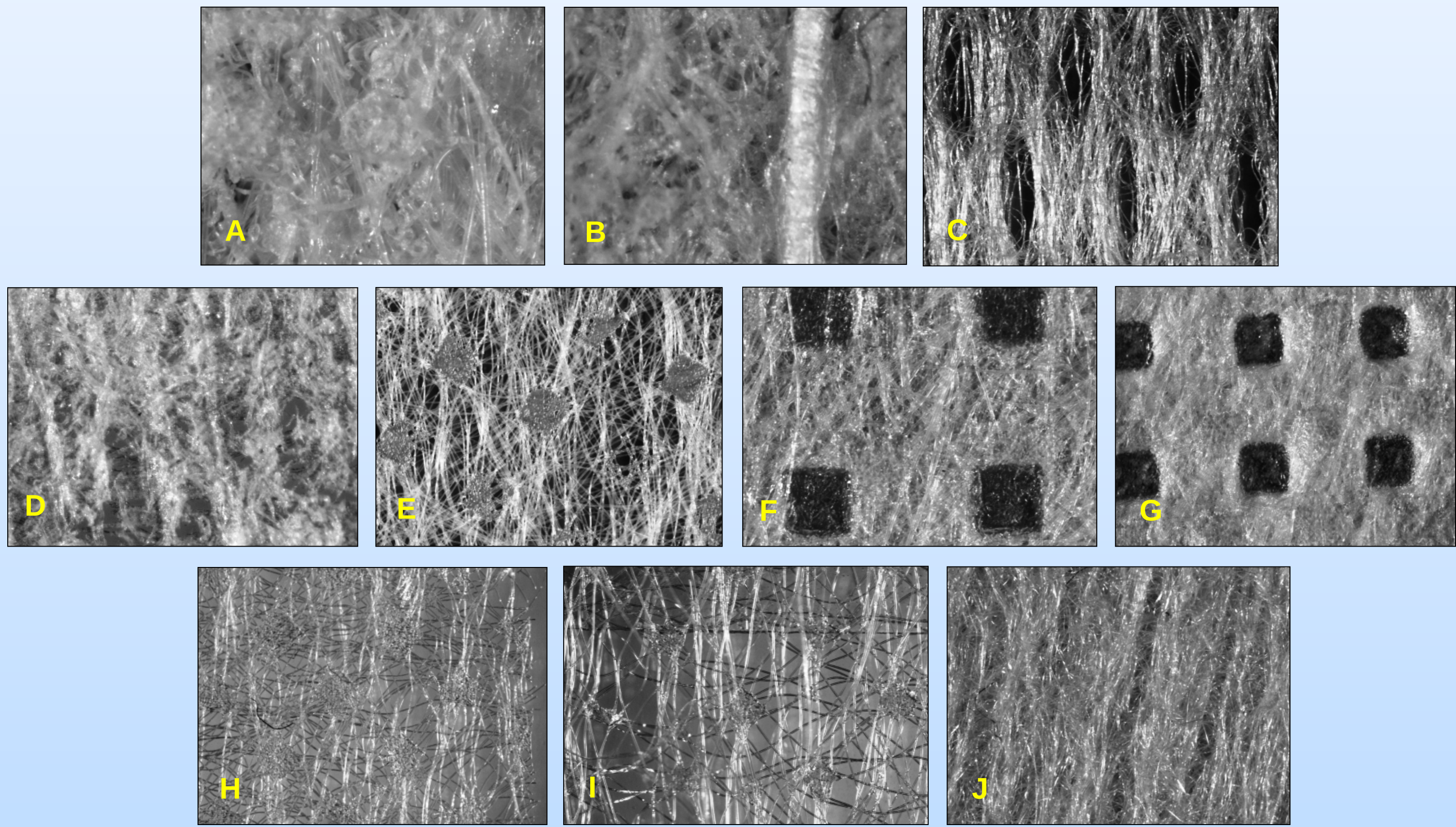


Figure 2. Optical microscope images of the nonwoven fabrics

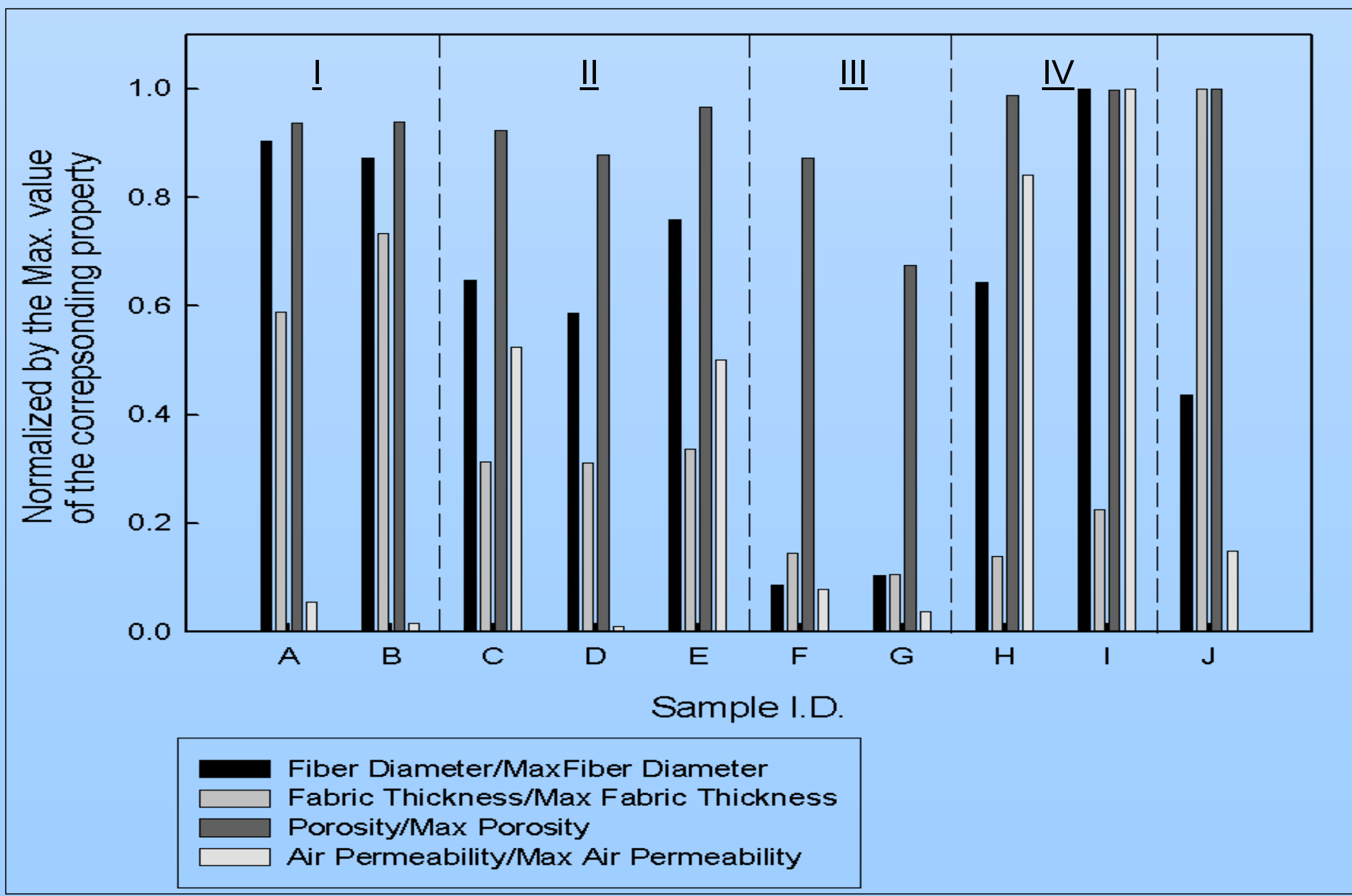


Figure 3. Physical properties of the nonwoven fabrics

Results and Preliminary Findings

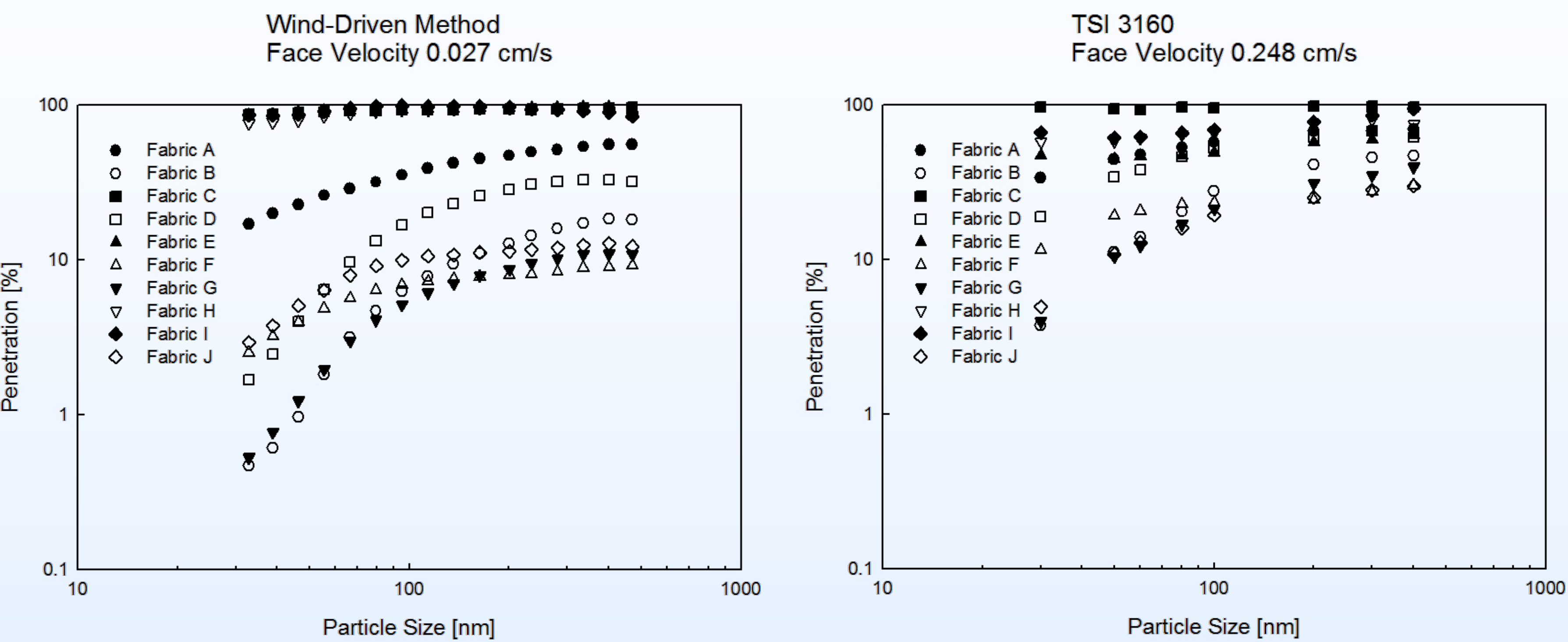


Figure 4. Penetration measurements of the nonwoven fabrics using wind-driven method (left) and TSI 3160 (right). At the highest wind velocity of 5 m/s, a maximum fabric face velocity of 0.027 cm/sec resulted, while the lowest face velocity by filtration was limited to 0.248 cm/sec.

- Particle penetration is correlated with physical properties, such as fiber diameter, fabric thickness, porosity, and air permeability.
- For both test methods, overall penetration trends are similar for all fabrics, with particle penetration increasing with particle size and reaching a maximum (i.e., Most Penetrating Particle Size or MPPS) at 300 to 500 nm. With increasing face velocities, penetration increases and the MPPS of some fabrics slightly shifts to a smaller size.
- However, filtration performances between fabrics are significantly different. For example, by the wind-driven method with a face velocity of 0.027 cm/s, penetration at 300 nm varied from 8% to nearly 100%.
- The wind-driven method is comparable to a standard filter test method, but uses face velocities that more closely represent natural conditions. This new method should be investigated further as an alternate procedure for measuring particle penetration through protective clothing materials.

Acknowledgements

The authors gratefully acknowledge Dr. Zhong-Min Wang currently with the California Department of Public Health for conducting some preliminary experiments; Dr. Samy Rengasamy at NIOSH and Dr. Claudiu Lungu at University of Alabama at Birmingham for helpful discussions; and NIOSH colleagues including Drs. Mark Hoover, Ralph Zumwalde, and Li-Ming Lo for their constructive comments.

Disclaimer: The findings and conclusions in this poster have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.